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WATER QUALITY SURVEY OF CHESAPEAKE BAY IN THE VICINITY OF ANNAPOLIS, MARYLAND

Federal Water Pollution Control Administration
Charlottesville, Virginia

1967

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I. INTRODUCTION

In the summer of 1967 water quality reconnaissance surveys were conducted in the Chesapeake Bay in the vicinity of Annapolis, Maryland.

Objectives of the surveys were:

1. Observe oxygen depletion trends during the summer months,
2. Determine horizontal and vertical stratification through thermoclines and haloclines,
3. Measure existing water quality in terms of D.O., BOD, temperature, salinity, nutrients, turbidity and phytoplankton.

During the surveys three cruises were made, covering five transects from a north section above Gibson Island to the southernmost section at Hacketts Point near Annapolis. Locations are shown on the map, Figure 1; positions are indicated in Table 1. Depth profiles are presented as Figures 2 through 6.

II. PROCEDURES

Temperature was determined initially by a glass thermometer wired inside a transparent water sampler. When an electronic thermometer (integral with the induction salinometer) became available, *in situ* measurements were made. Salinity was determined *in situ* by the induction salinometer.

Secchi disc readings were made with a 12-inch (30 cm) white Secchi disc.

Dissolved oxygen samples were drawn from a Van Dorn water sampler and fixed aboard the boat prior to being returned to the laboratory at Annapolis. These samples were analyzed on an (Fisher "Titralyzer") automatic titrator, employing the azide modification of the Winkler Method described in Standard Methods (APHA, 1965).

Standard 20°C five-day BOD determinations were made with single initial DO and duplicate final DO analyses. No dilutions or seeding were used.

Turbidity was determined in the laboratory with an electric nephelometric turbidimeter, calibrated against a permanent formazin-acrylic standard.

Total phosphorus (expressed as mg/l PO_4) was determined by the Menzel and Corwin (1965) persulfate procedure, with phosphate determination by the Murphy and Riley (1962) procedure.

Oxidized nitrogen (nitrite-plus-nitrate) expressed as NO_3-N, was determined by the cadmium reduction procedure described by Morris and Riley (1963).

Total Kjeldahl Nitrogen (TKN) was determined by the procedure outlined in Standard Methods for the Analysis of Waters and Wastewaters (APHA, 1965). This method included NH_3-N in the results.

Chlorophyll was determined by the 90 per cent acetone extraction scheme outlined by Strickland and Parsons (1965).

III. RESULTS

The data, as given in Table 2, are summarized as follows:

Temperature: Horizontal and vertical stratification of temperature were indicated in the study area portion of the Bay. Temperatures were observed to be a degree or so warmer on the western side of the Bay than on the eastern. A greater degree of vertical stratification of temperature was evident, with a 6°C difference between surface and bottom recorded. A rather sharp thermocline between 15 and 30 feet was suggested, more pronounced in June than in July.

Salinity: Salinity distributions showed horizontal and vertical stratification, with higher salinities on the western side. The rather sharp halocline seemed to be at similar levels as the thermocline.

Turbidity: Water in the eastern side of the Bay was substantially clearer than on the western side as indicated by turbidity readings (JTU) from the nephelometer as well as by field measurements of extinction with the Secchi disc. During the study no excessive rainfalls or windstorms occurred to provide excessive silts.

Nutrient distributions: Total phosphorus concentrations were greatest in the northwestern portion of the study area, with a tendency for greater concentrations above the halocline. Generally, concentrations were higher on the western side than the eastern side of the Bay.

Nitrite-plus-nitrate nitrogens were generally low, with slightly greater concentrations in the upper layers of the northerly transects.

Total Kjeldahl nitrogen was similar in horizontal distribution to total phosphorus, with greatest concentrations in the northwestern portion. The vertical distribution differed, however, with a tendency for similar concentrations of organic nitrogen throughout the water column, or in some cases, greater concentrations of nitrogen at increasing depths.

Chlorophyll, reflecting the phytoplankton standing crop, was greatest in concentration in surface waters (to 15 feet depth) in the same areas where phosphorus and nitrogen were high. There was a marked decrease in concentration with depth, as would be expected.

The trend toward oxygen depletion below concentrations suitable for aerobic biological forms can be seen in waters from 25 feet to the bottom. In the area of the study, the depth below 25 feet constitutes a considerable portion of the Bay volume. This oxygen depletion of the bottom waters was obvious even in the channel (Stations A2, B2 and C2). Tidal currents in the area are relatively rapid, two to three knots (Pritchard and Carpenter, 1964).

Dissolved oxygen concentrations in surface waters showed definite discrete patterns which, considered with the chlorophyll *a* data, indicated the influence of phytoplankton distributions,

possibly in bloom proportions. Oxygen production by phytoplankton was suggested in the northwestern portions of the study area where chlorophyll was highest.

The distribution of Biochemical Oxygen Demand was similar to the distribution of chlorophyll and nutrients, i.e., concentrations were greatest in the northwestern portion of the study area. Surface waters contained more oxygen-demanding material (BOD) than bottom waters.

IV. DISCUSSION

Temperature and salinity distributions, showing the laterally unequal patterns suggested by Pritchard (1952), are due to the effect of Coriolis forces on Chesapeake Bay. Vertically, the thermocline and halocline that develop in the warmer months were already present, and because of time and personnel limitations, the study was too short to determine maximum extent during the late summer or to detect the fall overturn.

The distribution of nutrients seemed to follow the western side of the Bay above Sandy Point, probably because of the proximity to sources as well as the location of the channel on the western side. Phosphorus and nitrate-nitrite nitrogen seemed to be greatest in the mixed layer (i.e., above the thermocline and halocline), but the distribution of total Kjeldahl nitrogen (TKN) throughout the water column needs further elucidation. The distribution of TKN would be expected to parallel total phosphorus, but this was apparently not the case, judging from limited data available.

The standing crop of phytoplankton, as reflected in chlorophyll measurements, paralleled the nutrient distribution in surface waters, with a fairly large bloom indicated just above the study area on the two days of sampling of this parameter. This distribution suggests that urban pressures on the western shore, from Annapolis to Baltimore, may be causing accelerated eutrophication of Bay waters in this area, but more observations are needed to confirm this possibility.

Light extinction, as measured by Secchi disc, did not reflect the distribution of chlorophyll, and is apparently at best a gross index with more value over annual cycles than synoptic differentiation in this area.

Of interest is the relationship developed between Secchi disc readings and nephelometric turbidity measurements in the study area (Figure 7). Analyzed by linear regression, the following equation was developed:

$$\text{Turbidity} = -0.312 \text{ Secchi disc} + 18.00$$

This regression fits at the one per cent level of significance. Extrapolation of this relationship to conditions other than this study would not necessarily be valid; seasonal changes and varied runoff patterns would probably affect the slope of the regression line, if not the validity of the relationship itself. The regression fit suggests that a properly related turbidity-extinction relationship could possibly be used in other studies under relatively constant conditions, and that possibly solids could also be considered from known relationships of turbidity and solids.

The study period, June-July 1967, can be considered early summer of a "typical" year, with no extremes of flow or temperature. Unfortunately, the more critical late summer (August-September) period was not evaluated because of other committments of time and personnel. The dissolved oxygen depletion below approximately 25 feet is evident; however, greater depletion can be expected later in the summer than this study period.

In this study, BOD of the water only is considered, and the oxygen demands exerted by bottom deposits are not included. The greatest concentration of BOD in the waters was found in the upper layers, and a regression analysis of BOD and chlorophyll showed a very close relationship, in the range from 1 to 10 mg/l BOD, viz.,

$$\text{Chlorophyll } \underline{a} = 10.36 \text{ BOD} - 4.80$$

This relationship suggests that most of the BOD in the waters was due to the phytoplankton standing crop, and a lesser contribution from organic loadings, i.e., sewage or other water-borne effluents. This relationship would not necessarily imply that all of the oxygen depletion found was due to decomposition of the phyto-biota because benthic uptake, discharge of oxygen-poor water into the area, reaeration, and chemical oxidation, among other factors, must be considered in a total oxygen budget.

The exceptionally good BOD-chlorophyll regression fit developed above, for an area where organic loadings are small relative to chlorophyll, suggested a possible method for assessing relative demands in an area where both organic loading and accelerated eutrophication are important factors. If a fairly constant relationship between BOD and chlorophyll could be established in areas with little or no organic loading from sewage or other waste effluents, then analysis of variance might be used to evaluate relative demands in an area with both chlorophyll and significant organic loadings.

It appears that, at the time of this study, the BOD in the water column was primarily due to phytoplankton. Also, it appears that, with present oxygen deficits and a relatively large phytoplankton standing crop, the Chesapeake Bay in this region should be carefully evaluated to determine the allowable organic loadings (from sewage treatment plants) and secondary eutrophication effects without creating serious oxygen depletions in the mid-Bay region.

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TABLE 1

Station Locations in Chesapeake Bay

Summer 1967

Transect	Station	Location	Water Depth	USC & GS Chart No.
A	1	39° 05' 30" N 76° 24' 55" W Off tower at Windmill Point	17 Feet	549
	2	39° 05' 37" N 76° 23' 38" W Red flasher "1oc"	40 Feet	549
	3	39° 05' 43" N 76° 20' 57" W Black and white buoy "13B"	23 Feet	549
B	1	39° 03' 18" N 76° 25' 43" W Red flasher "2" Magothy River	15 Feet	549
	2	39° 03' 35" N 76° 23' 25" W Red nun "4C"	40 Feet	549
	3	39° 04' 34" N 76° 19' 43" W Black flasher, bell "1"	36 Feet	549
C	1	39° 02' 18" N 76° 24" 03" W Off house at Tydings-on-the-Bay	17 Feet	549
	2	39° 02' 55" N 76° 23' 06" W Red flasher, bell "2C"	50 Feet	549
	3	39° 02' 40" N 76° 20' 38" W Edge of dumping grounds	50 Feet	549
D	1	39° 00' 32" N 76° 23' 20" N Off Sandy Point	16 Feet	550
	2	38° 59' 57" N 76° 22' 42" N Red flasher, gong "8"	60 Feet	550
	3	38° 55' 30" N 76° 21' 12" N South edge of dumping ground	25 Feet	550
E	1	38° 58' 58" N 76° 24' 47" N Off Hacketts Point	17 Feet	550
	2	38° 58' 33" N 76° 23' 12" N Red flasher, gong "4"	55 Feet	550
	3	38° 57' 30" N 76° 21' 42" N Off Matapeake ferry slip	16 Feet	550

TABLE 2

Water Quality Parameters in Mid-Chesapeake Bay
Summer 1967

Transect	Station	Date	Time EST	Secchi Disc Inches	Water Depth Feet	Sample Depth Feet	Water Temp. °C	Salinity	DO mg/l	BOD mg/l	Turbidity JTU	Total P mg/l PO_4	NO_3+NO_2-N mg/l	TKN mg/l	Chlorophyll ugm/l	Wind	Sea State
A	1	6/20/67	1300	18	17	Surface	22		9.13		16					NE 10	Moderate
						15'	21		8.34								
	2		1240	24	40	Surface	22		8.65	2.87	11						
					(Channel)	15'	21		6.91								
						25'	18		3.41	3.87	17						
	3			30	23	Surface	21		8.34		8						
						15'	20		6.75								
A	1	6/26/67	1300	24	17	Surface	23		10.10		12					NW 5 - 10	Moderate
						15'	22		8.46								
	2		1330	26	40	Surface	23		11.38		13						
						15'	21		5.27								
						25'	18		2.59								
	3		1345	42	23	Surface	22		7.57		5						
						15'	21		5.23								
A	1	7/18/67	1245	28	17	Surface	25.6	7.1	8.58	3.97		0.21	0.13	0.70	34.5	Variable	Calm
						15'	24.9	7.9	5.11	2.38		0.35	0.10	0.82	31.5		
	2		1220	28	50	Surface	26.3	6.6	11.18	8.48		0.36	0.15	1.12	108.0		
					(Channel)	15'	23.8	8.9	4.82	4.22		0.31	0.13	0.70	26.25		
						30'	21.4	13.3	1.45	1.56		0.22	0.06	0.78	11.25		
						45'	20.6	14.5	0.77	1.79		0.12	0.04	0.63	7.50		
	3		1205	58	23	Surface	25.7	5.5	7.81	2.90		0.14	0.04	0.36	27.75		
						15'	22.7	11.3	2.41	2.29		0.14	0.09	0.59	11.25		
B	1	6/20/67	1015	17	19	Surface	21		7.23	2.39	18					NE 5	Moderate
						15'	20		6.99	1.25	18						
	2		1045	34	40	Surface	21		7.62		8						
					(Channel)	15'	20		7.07								
						30'	19		1.11								
	3		1145	28	36	Surface	22		9.13		9						
						15'	20		7.15								
						30'	19		0.56								
B	1	6/26/67	1125	26	13	Surface	23		7.23		12					NW 10	Moderate
						13'	22		6.81								
	2		1230	28	40	Surface	22		8.40		7.5						
						15'	22		6.68								
						30'	19		LA								
						45'	16		0.92								
	3		1330	42	36	Surface	22		8.37		3.5					NW 2-3	Calm
						15'	22		6.70								
						30'	16		1.02								
B	1	7/18/67	1014	42	12	Surface	25.4	7.5	7.81	4.88		0.27	0.07	0.86	94.00	Variable	Calm
						12'	23.0	7.6	3.33	3.39		0.37	0.06	0.86	45.00		
	2		1030	42	40	*Surface	26.0	7.3	5.22	4.07		0.20	0.18	0.52	30.25		
						15'	24.3	9.9	4.34	2.25		0.15	0.05	0.46	21.00		
						30'	21.3	13.3	1.93	1.01		0.19	0.06	0.79	15.00		
						45'	20.2	14.8	0.53	1.09		0.39	0.06	0.80	21.00		
	3		1110	42	36	Surface	25.1	8.0	8.20	2.91		0.20	0.10	0.67	28.50		
						15'	24.3	8.1	5.21	2.95		0.15	0.06	0.50	15.75		
						30'	21.7	14.0	1.01	1.37		0.18	0.11	0.67	12.00		
C	1	6/16/67	-	35	17	Surface	22		9.06		7					SW 5-10	Moderate
						15'	21		5.75								
	2		-	42	50	Surface	21		11.00		5						
						15'	20		4.91								
						30'	20		8.09								
						45'	18		2.32								
	3		-	-	50	Surface	21		11.66		4						
						15'	20		9.33								
						30'	19		5.50								
						45'	16		1.02								
C	1	6/26/67	1150	20	16	Surface	23		9.63		10					NW 10	Moderate
						15'	22		7.84								
	2		1205	32	50	Surface	22		8.26		7						
						15'	22		7.39								
						30'	16		1.53								
						45'	16		0.78								
C	1	7/19/67	1005	34	17	Surface	25.8	7.1	8.97	5.80		0.31	0.10	1.15	27.75	SE 3	Calm
						15'	24.0	9.2	4.77	2.71		0.20	0.09	0.88	24.00		
	2		1040	52	50	Surface	25.4	8.3	9.01	2.69		0.18	0.09	0.83	25.50		
						15'	24.6	8.9	7.81	2.76		0.21	0.08	0.64	9.75		
						30'	21.6	12.9	1.83	1.64		0.13	0.06	0.75	9.75		
						45'	21.1	13.7	0.63	1.98		0.20	0.06	0.77	18.75		
	3		1107	46	50	Surface	25.3	7.6		2.34		0.15	0.15	0.61	17.25		
						15'	24.6	9.3	6.75	2.67		0.15	0.07	0.74	9.75		
						30'	22.0	12.6	2.27	1.62		0.14	0.07	0.70	38.25		
						45'	19.9	15.1	0.96	2.37		0.46	0.07	1.04	28.5		

* Mid-channel

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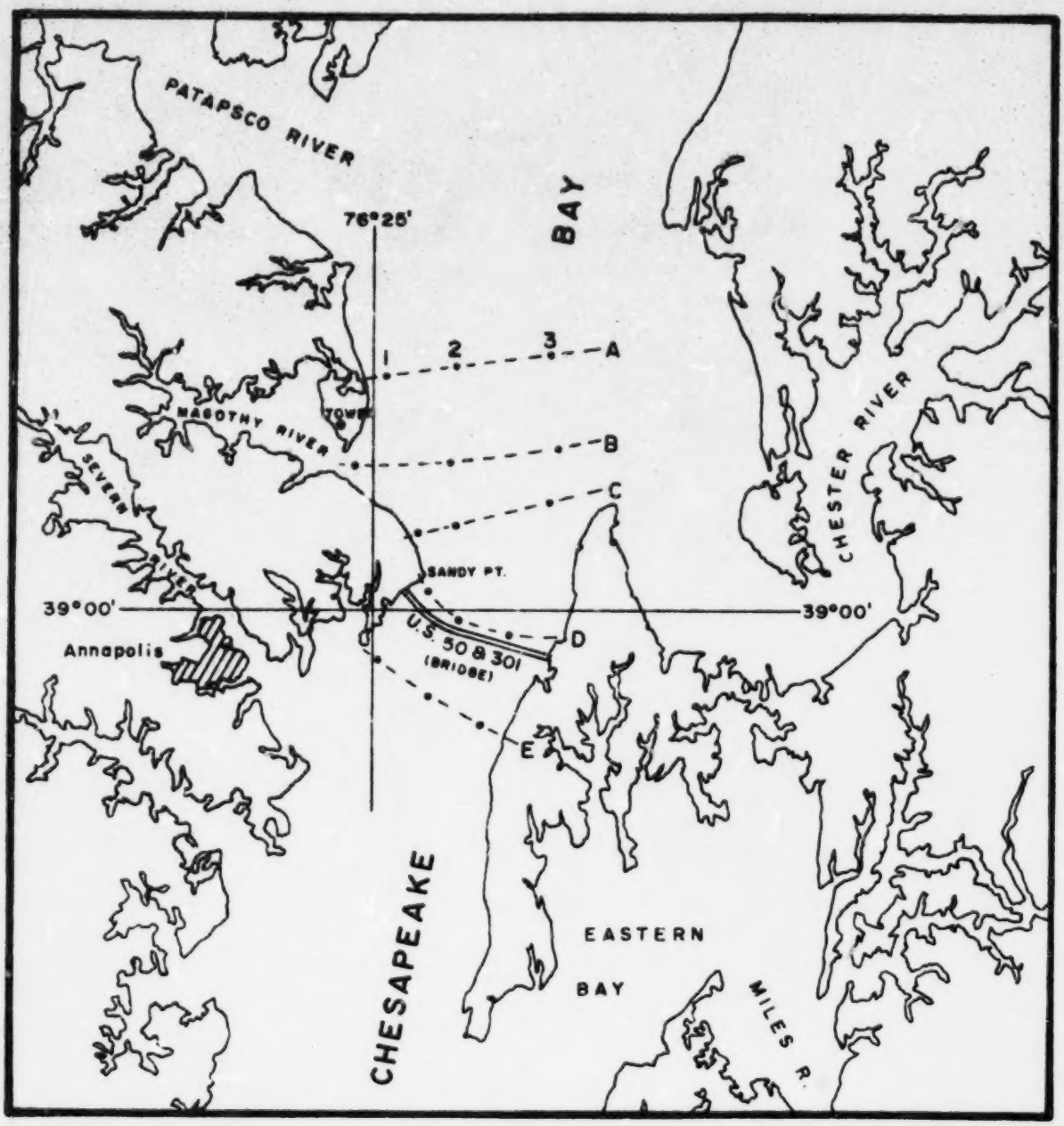
TABLE 2 (Continued)

Transect	Station	Date	Time EST	Secci Disc Inches	Water Depth Feet	Sample Depth Feet	Water Temp. °C	Salinity	DO mg/l	BOD mg/l	Turbidity JTU	Total P mg/l PO_4	NO_2+NO_3-N mg/l	TKN mg/l	Chlorophyll ugm/l	Wind	Sea State
D	1	6/14/67	1435	29	16	Surface	22		10.40		8					SW 3	Calm
						15'	21		9.52								
	2		1405	18	57	Surface	21		12.96		3						
						15'	20		8.88								
						30'	19		6.48								
						45'	14		0.72								
						60'	14		0.72								
	3		1340	44	23	Surface	21		7.68		6						
						15'	20		7.76								
D	1	6/22/67	1345	30	17	Surface	21		6.08		8					SE	Rough
						15'	20		5.72							15 - 20	
	2		1310	30	60	Surface	22		10.10	6.27	4						
						15'	21		7.52								
						30'	20		4.97								
						45'	18		3.02	1.33							
						60'	17		1.67								
	3		1245	38	25	Surface	22		8.37		6						
						15'	22		8.33								
D	1	7/19/67	1230	34	16	Surface	25.1	8.4	-	2.36		0.24	0.08	0.80	23.25	SE 3	Calm
						15'	24.7	8.5	6.22	2.22		0.25	0.08	0.85	18.00		
	2		1210	48	60	*Surface	25.7	7.9	LA	2.61		0.16	0.18	0.61	22.50		
						15'	24.8	9.1	7.62	2.74		0.19	0.05	0.55	14.25		
						30'	21.4	13.2	3.23	1.17		0.17	0.07	0.60	6.75		
						45'	20.5	14.6	0.67	1.40		0.18	0.06	0.66	6.75		
						60'	20.3	14.9	0.67	1.29		0.16	0.04	0.58	-		
	3		1135	54	25	Surface	25.6	8.7	7.90	2.08		0.13	0.05	0.48	17.25		
						15'	24.0	10.1	4.92	3.11		0.13	0.07	0.67	13.50		
E	1	6/14/67	1100	32	17	Surface	22.5		9.92		7					SW	Moderate
						15'	21		9.04							2 - 3	
	2		1125	36	55	Surface	21		10.32		8						
						15'	20		8.96								
						30'	19		7.28								
						45'	18		5.12								
	3		1140	44		Surface	21		8.00		3						
						15'	21		7.52								
E	1	6/22/67	1015	40	17	Surface	22		8.45		7					S	Moderate
						15'	21		6.99							5 - 10	
	2		1045	40	49	Surface	22		7.98	3.31	6						
						15'	22		7.94								
						30'	18		2.94								
						45'	15		0.04	2.03							
	3		1115	34	16	Surface	22		7.82		7						
						15'	22		7.71								
E	1	7/14/67	1300	-	17	Surface	26		8.92							S	Choppy
						15'	25		6.01							10 - 15	
	2			-	50	Surface	25		9.23								
						15'	24		6.47								
						30'	21		2.35								
						45'	20		1.31								
E	1	7/19/67	1255	38	17	Surface	26.0	8.2	8.15	3.08		0.24	0.07	0.55	33.75	SE 3	Calm
						15'	23.9	10.1	4.63	1.14		0.20	0.06	0.66	11.25		
	2		1315	48	50	Surface	25.8	8.8	8.48	4.05		0.25	0.05	0.61	30.75		
						15'	24.4	9.3	1.93	2.31		0.19	0.06	0.65	18.00		
						30'	21.6	12.9	1.93	1.85		0.19	0.05	0.86	6.75		
						45'	20.3	15.0	LA	1.15		0.17	0.05	0.81	6.75		
	3		1335	48	16	Surface	26.7	8.9	8.92	2.18		0.20	<0.02	0.79	18.75		
						15'	24.7	9.8	LA	1.62		LA	0.06	0.58	18.75		

* Mid-channel



STATION LOCATIONS

CHESAPEAKE FIELD STATION SURVEY OF
CHESAPEAKE BAY
SUMMER, 1967

FIGURE 1

BOTTOM PROFILE OF TRANSECTS OBSERVED BY C. F. S., SUMMER, 1967
TRANSECT A

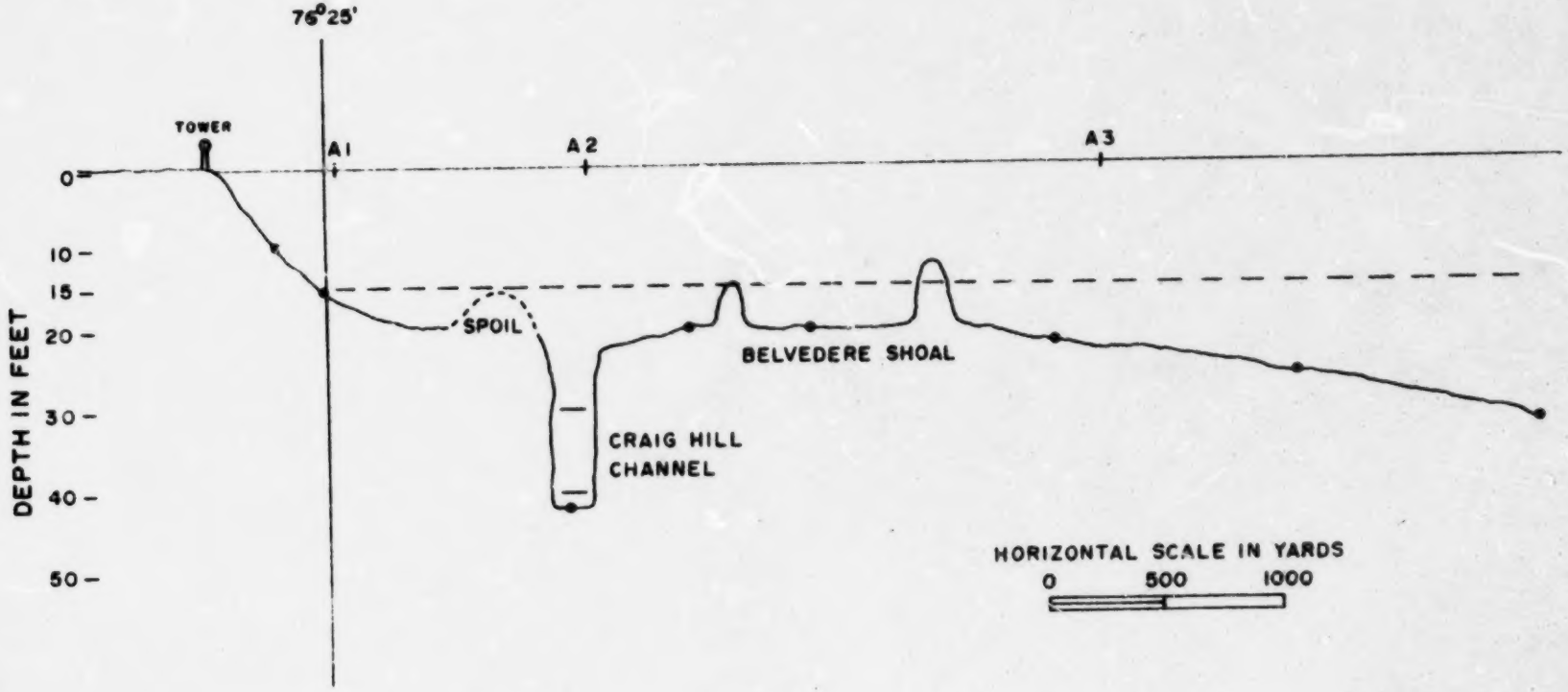


FIGURE 2

BOTTOM PROFILE OF TRANSECTS OBSERVED BY C.F.S., SUMMER, 1967
TRANSECT B

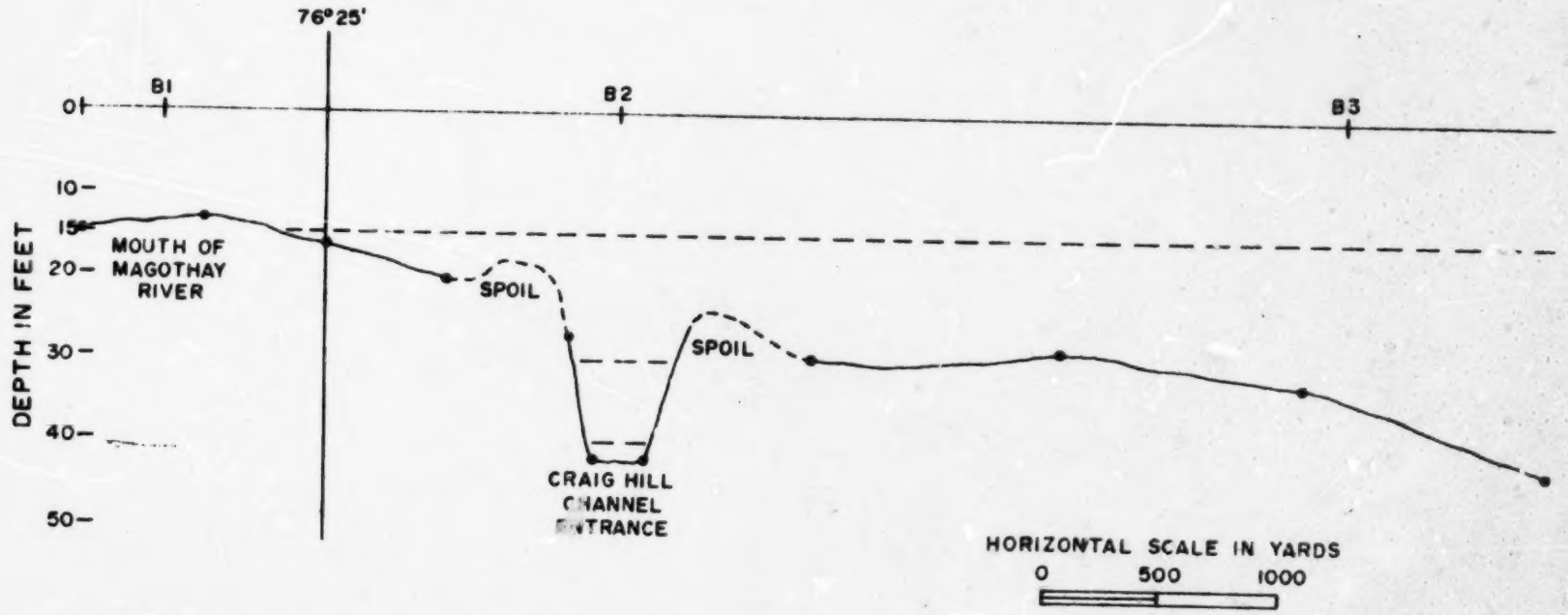


FIGURE 3

BOTTOM PROFILE OF TRANSECTS OBSERVED BY C.F.S., SUMMER, 1967
TRANSECT C

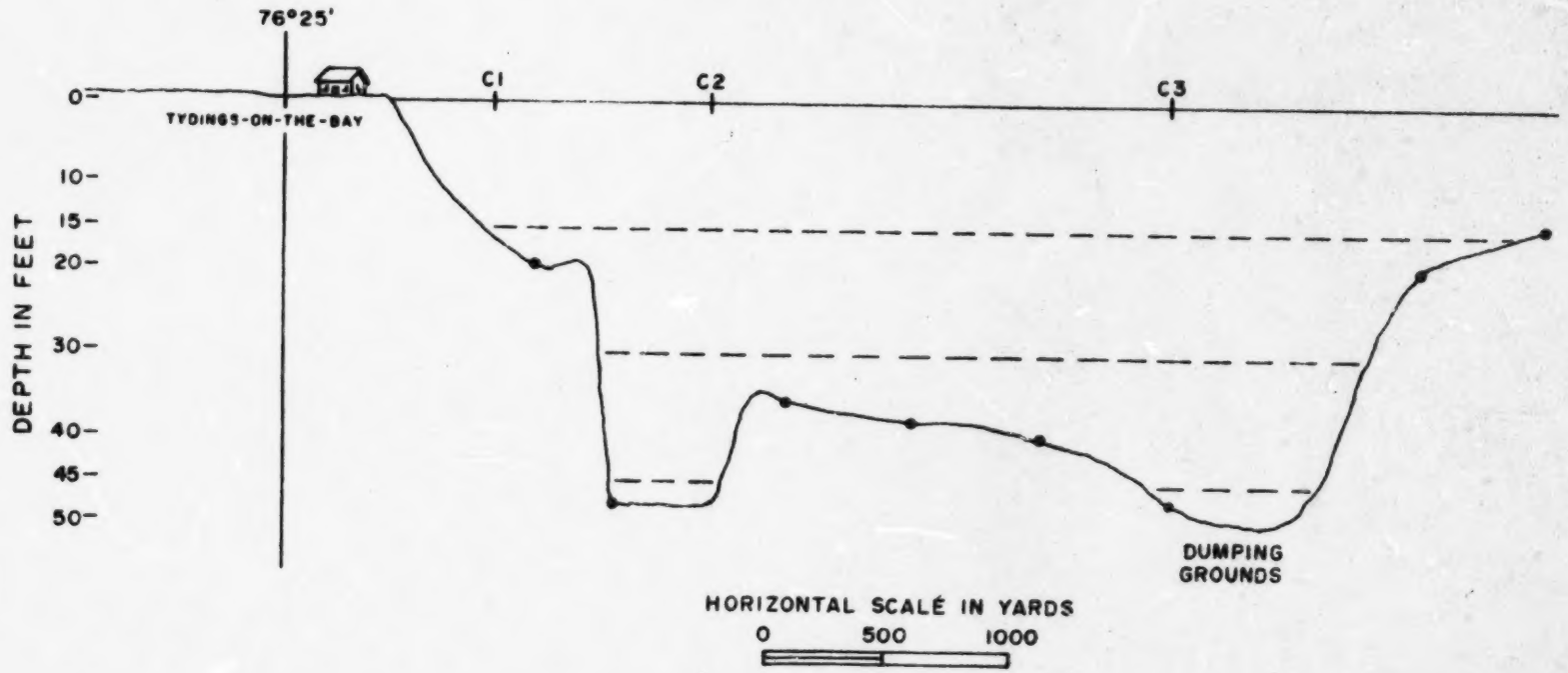


FIGURE 4

BOTTOM PROFILE OF TRANSECTS OBSERVED BY C.F.S., SUMMER, 1967

TRANSECT D

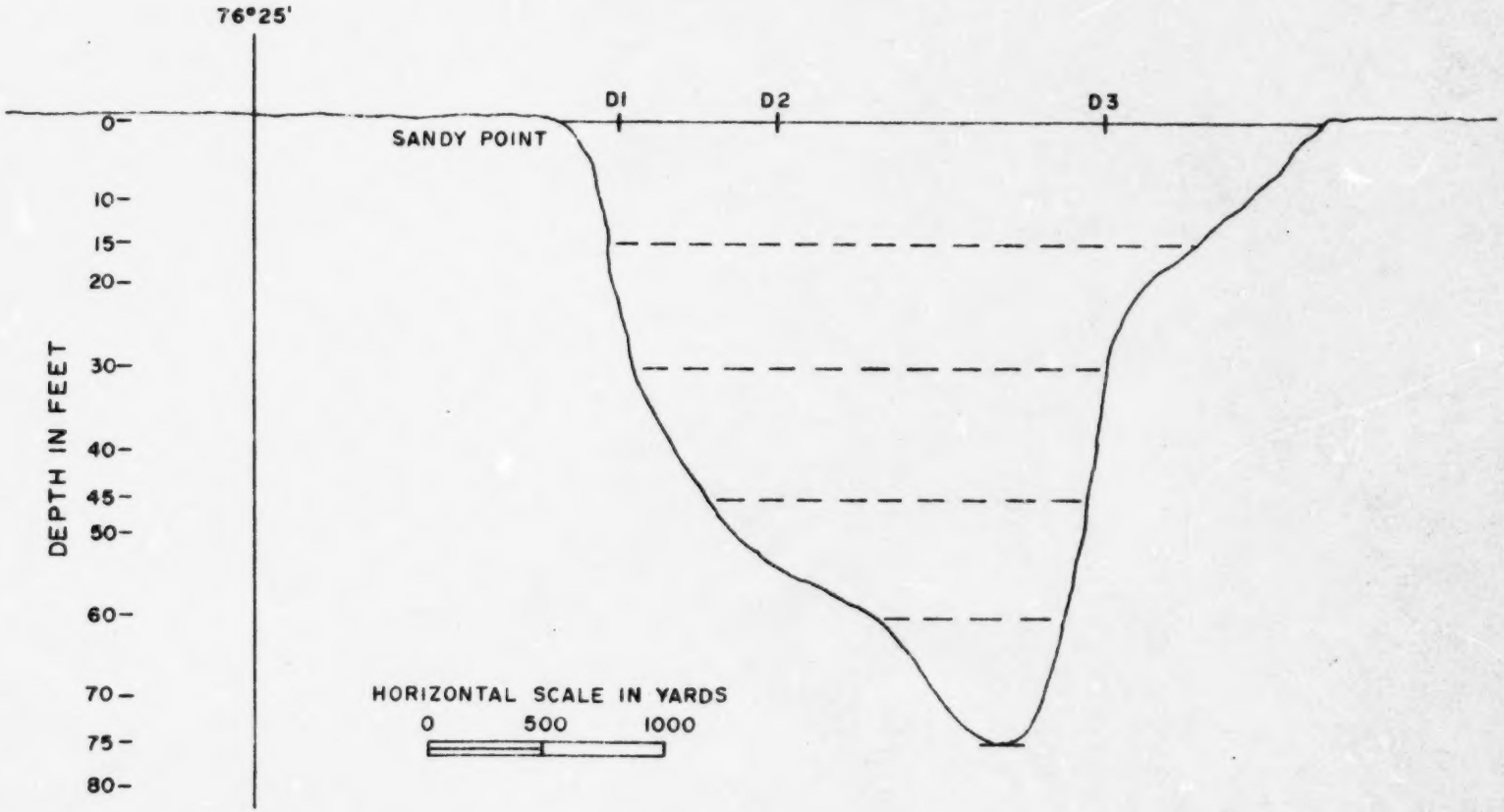


FIGURE 5

BOTTOM PROFILE OF TRANSECTS OBSERVED BY C. F. S., SUMMER, 1967
TRANSECT E

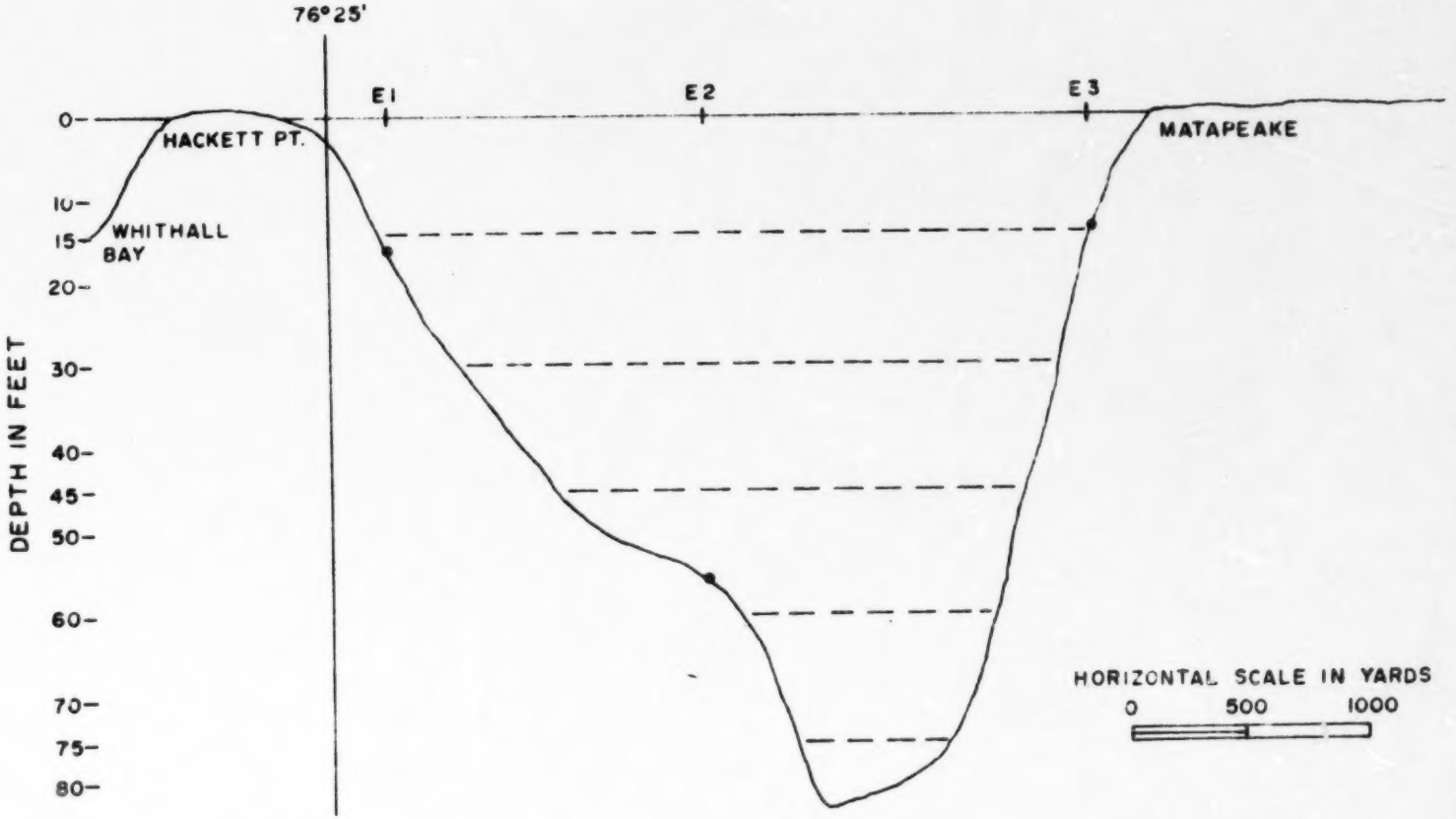


FIGURE 6

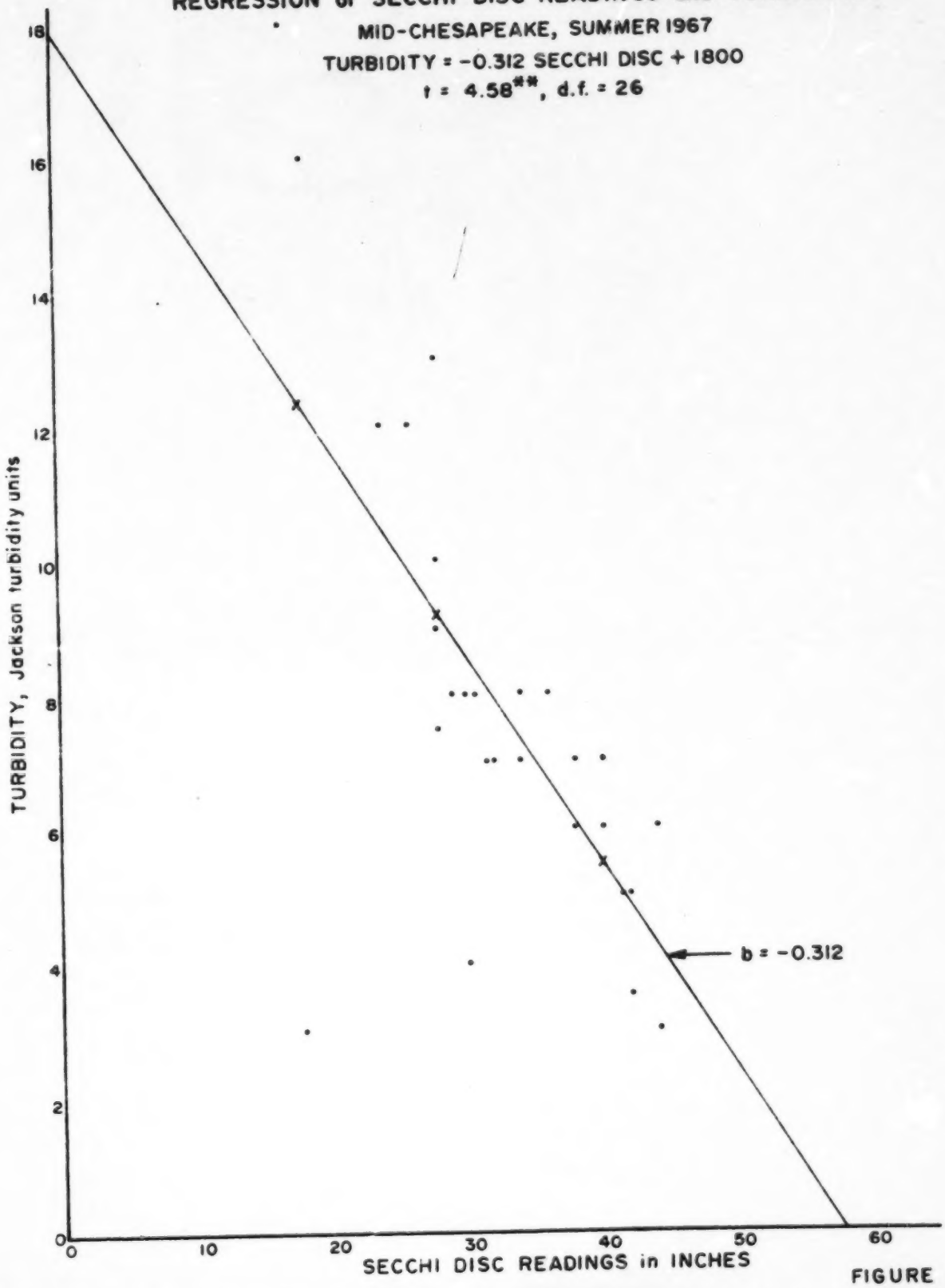

REGRESSION of SECCHI DISC READINGS and TURBIDITIES
MID-CHESAPEAKE, SUMMER 1967
TURBIDITY = -0.312 SECCHI DISC + 1800
t = 4.58**, d.f. = 26
TURBIDITY, Jackson turbidity units
0
2
4
6
8
10
12
14
16
18
b = -0.312
0
10
20
30
40
50
60
SECCHI DISC READINGS in INCHES

FIGURE 7

REGRESSION of BOD and CHLOROPHYLL a

CHLOROPHYLL a = 10.36 BOD - 4.80

$t = 9.03^{**}$, d.f. = 41

108

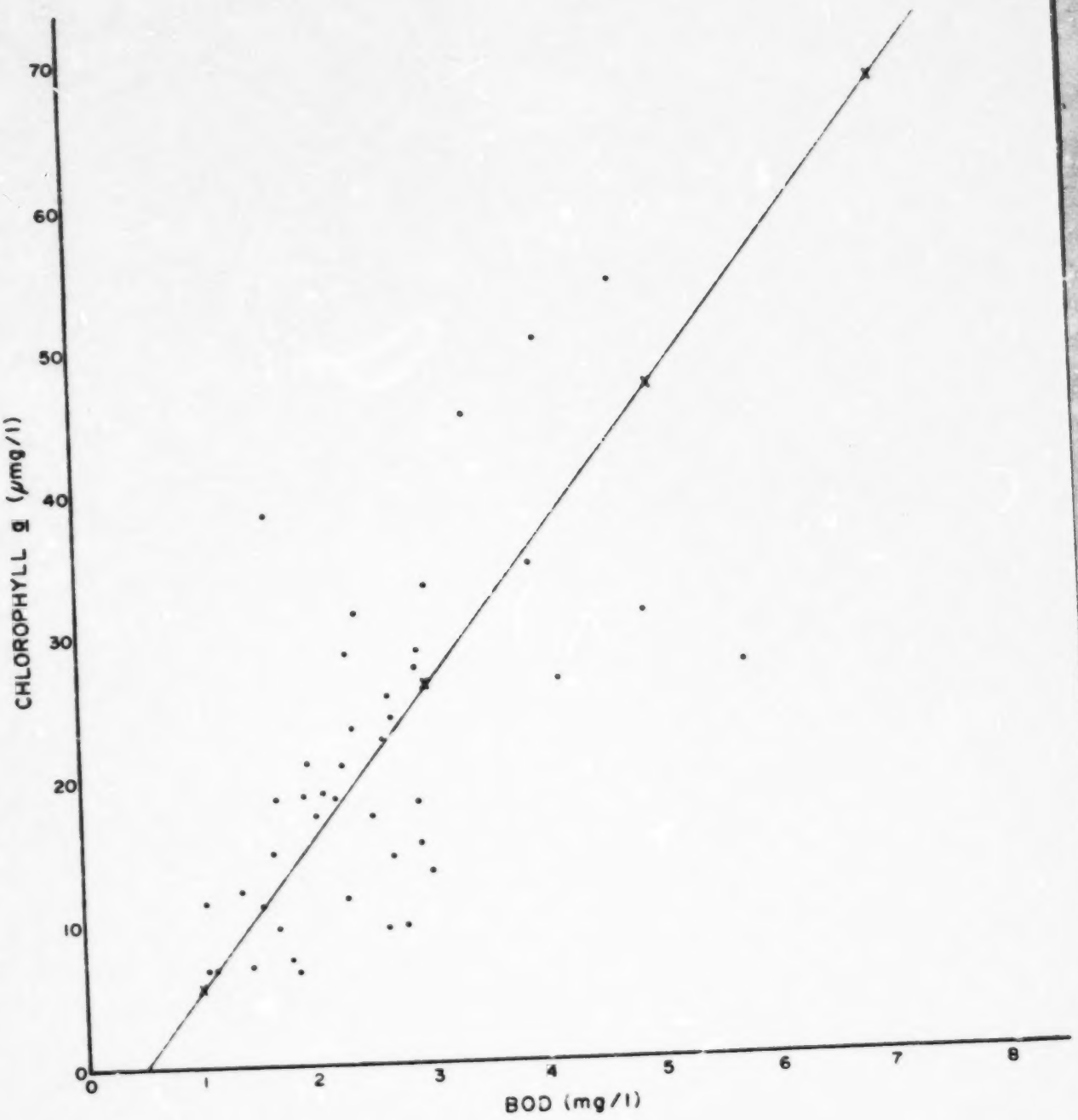


FIGURE 8